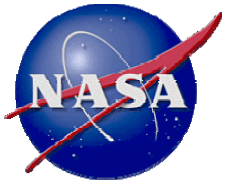
National Aeronautics and Space Administration



Optical Observations of Space Debris

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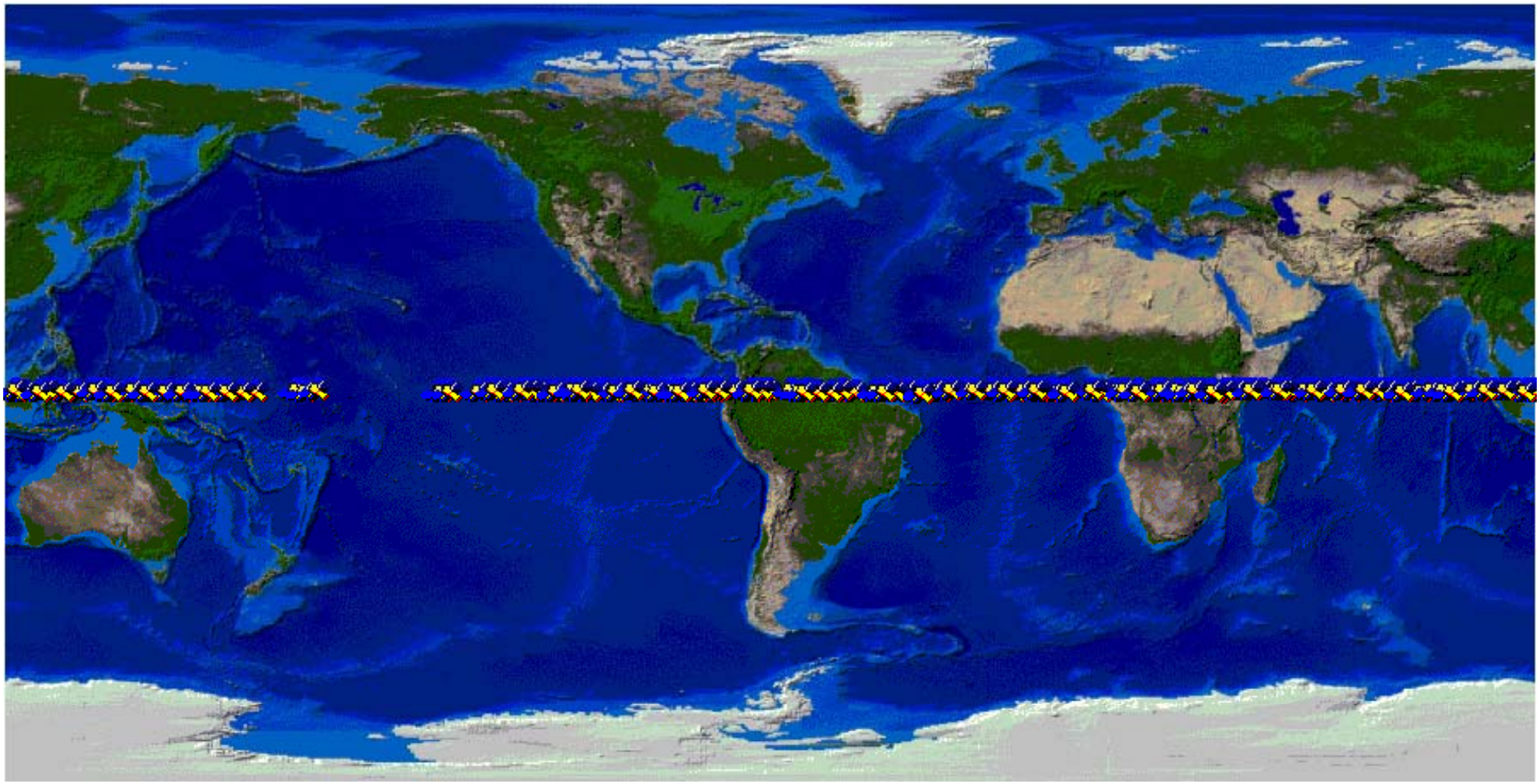
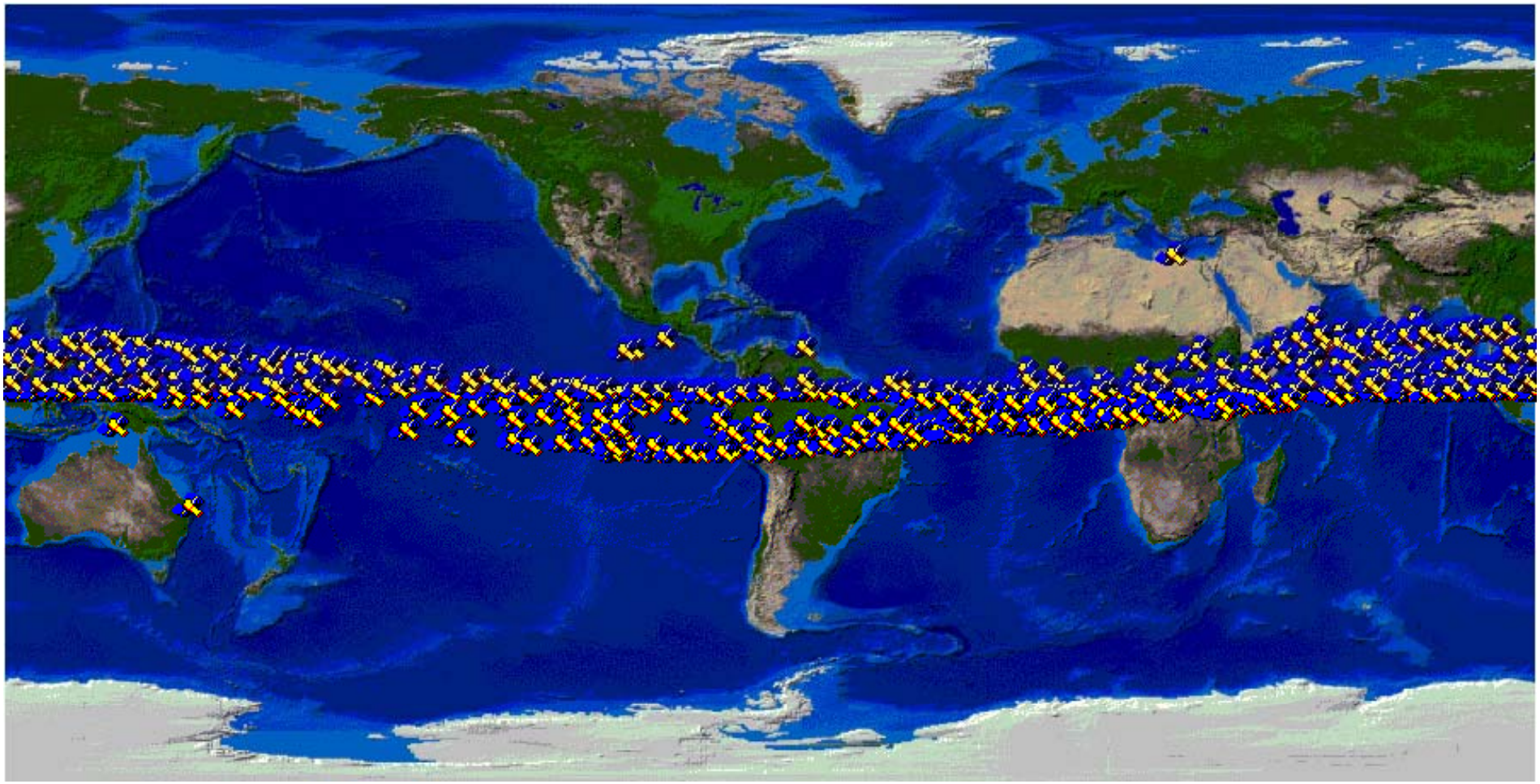
GEO Stationkeeping Satellites

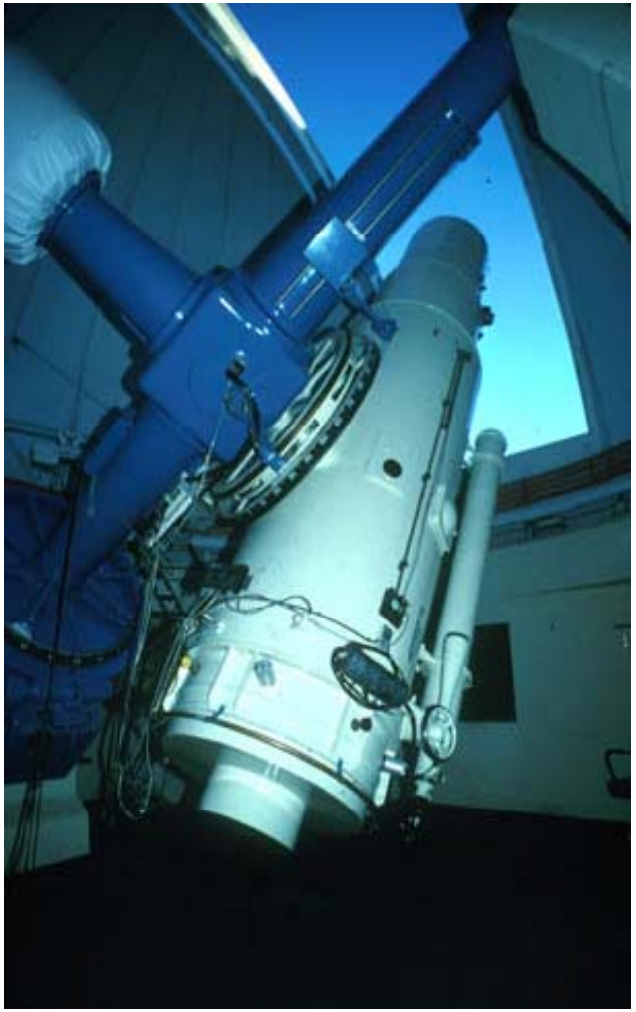


All Cataloged Objects at GEO



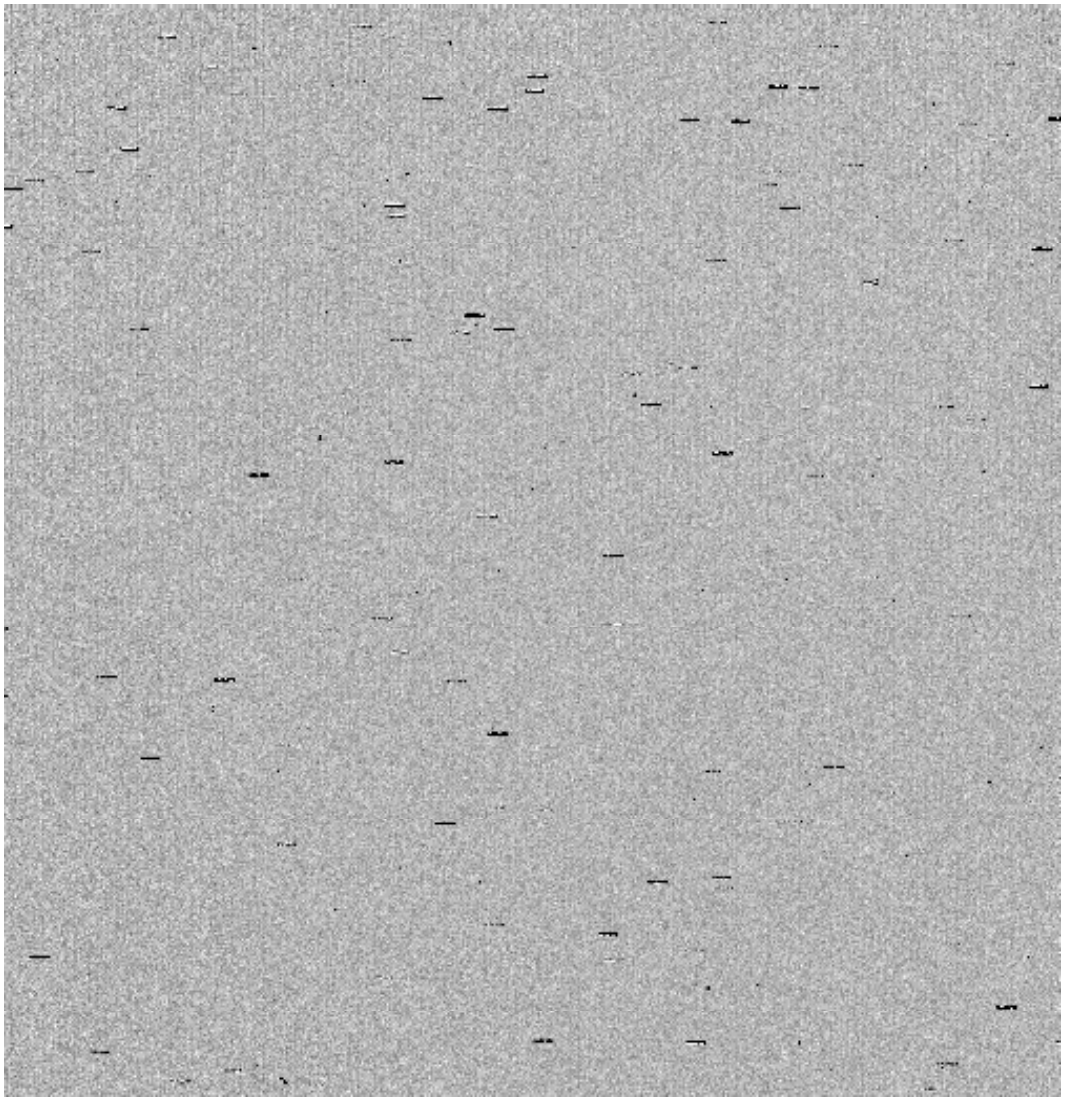
Cerro Tololo Inter-American Observatory

MODEST – Michigan Orbital DEbris Survey Telescope
the telescope formerly known as the Curtis-Schmidt

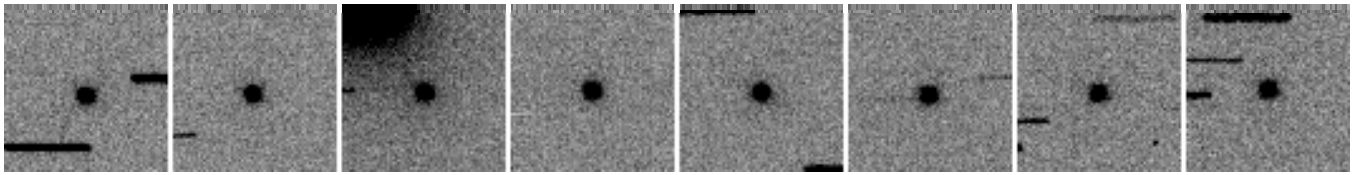


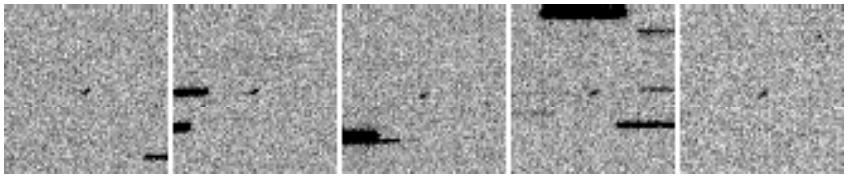
0.61/0.91-m Schmidt telescope
GEO debris survey began February 2001

MODEST Data Sample

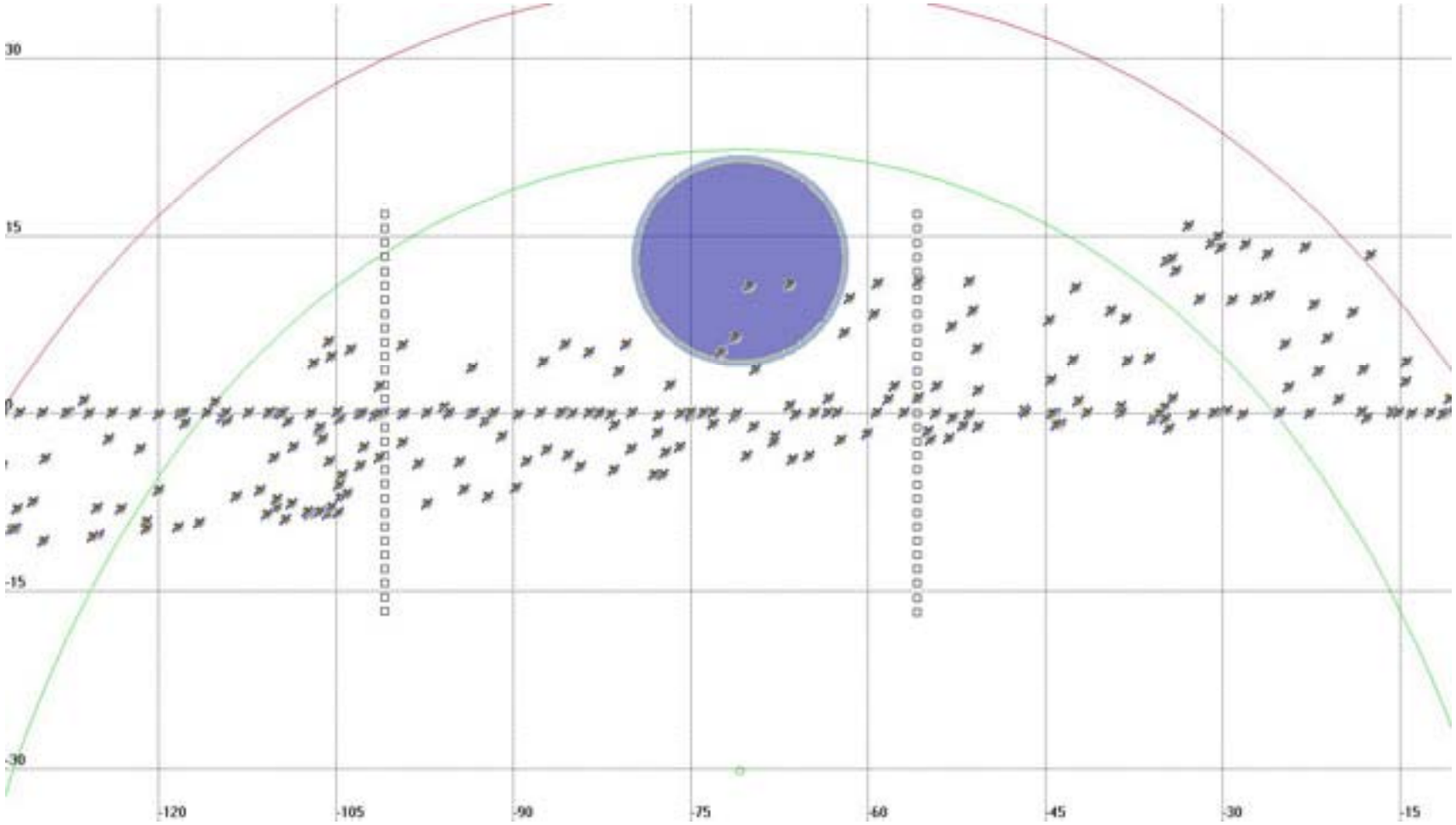


Examples of Detections

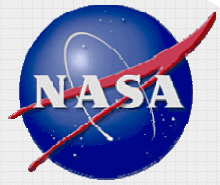




Use of STK for Observation Planning



GEO Debris Observations with Two Telescopes



- **Limitations of single telescope – incomplete survey or short arc for orbit.**

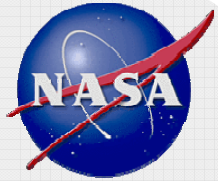
- **March 2007 – began observations with two telescopes at Cerro Tololo, Chile:**
  - MODEST survey telescope: 0.6/0.9-m Schmidt
  - CTIO 0.9-m telescope for follow-up

- **Goal – characterization of complete sample of faint GEO debris selected on basis of angular rates and brightness.**
  - Orbits
    - What fraction of objects selected on basis of magnitude and angular rates are really at GEO?
  - Brightness variations
  - Colors in standard astronomical filters.

CTIO 0.9-m

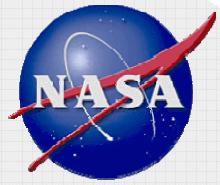
- **0.9-m Cassegrain**
- **0.22 deg FOV (small!)**
- **Track objects at their angular rates.**
- **Existing telescope and CCD.**
- **Debris project can obtain several weeks during the year of time on this telescope for GEO observations.**

Techniques and Results



- **Typical time between last MODEST observation and 1st 0.9-m observation less than 20 minutes. MODEST observations fit to circular orbit and prediction generated for 0.9-m.**
- **Recovery rate of MODEST detections on 0.9-m greater than 80%.**
- **After initial acquisition and follow-ups on 0.9-m: determine full six parameter orbit including eccentricity.**
- **Track objects from night to night**
  - Longest track is six nights on multiple objects in March 2007, March & August 2008.
  - Primary reason for loss of track is object moves too far east or west to be tracked from Chile.

Statistical Analysis



- **Use all available information from all sources to determine distribution of all objects found in MODEST survey strips.**

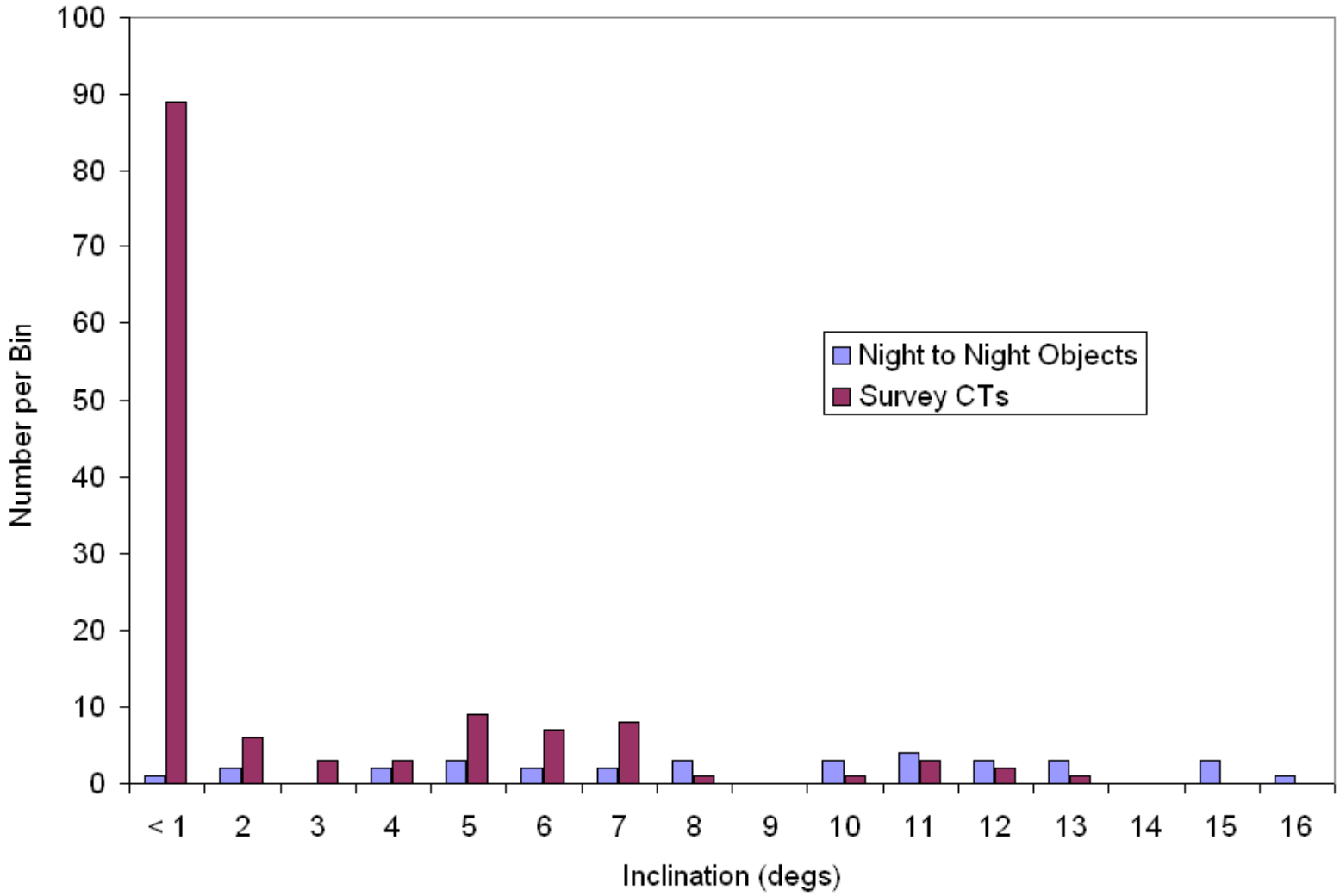
- **Bright objects found by MODEST not followed up by 0.9-m due to time constraints:**
  - Magnitudes from MODEST survey observations.
  - Orbits from public Space Command catalog.

- **Faint objects found by MODEST and followed up by 0.9-m:**
  - Magnitudes from MODEST survey observations to ensure on same system as bright objects (CTs) from catalog.
  - Orbits from full six parameter fit from both MODEST and 0.9-m observations.

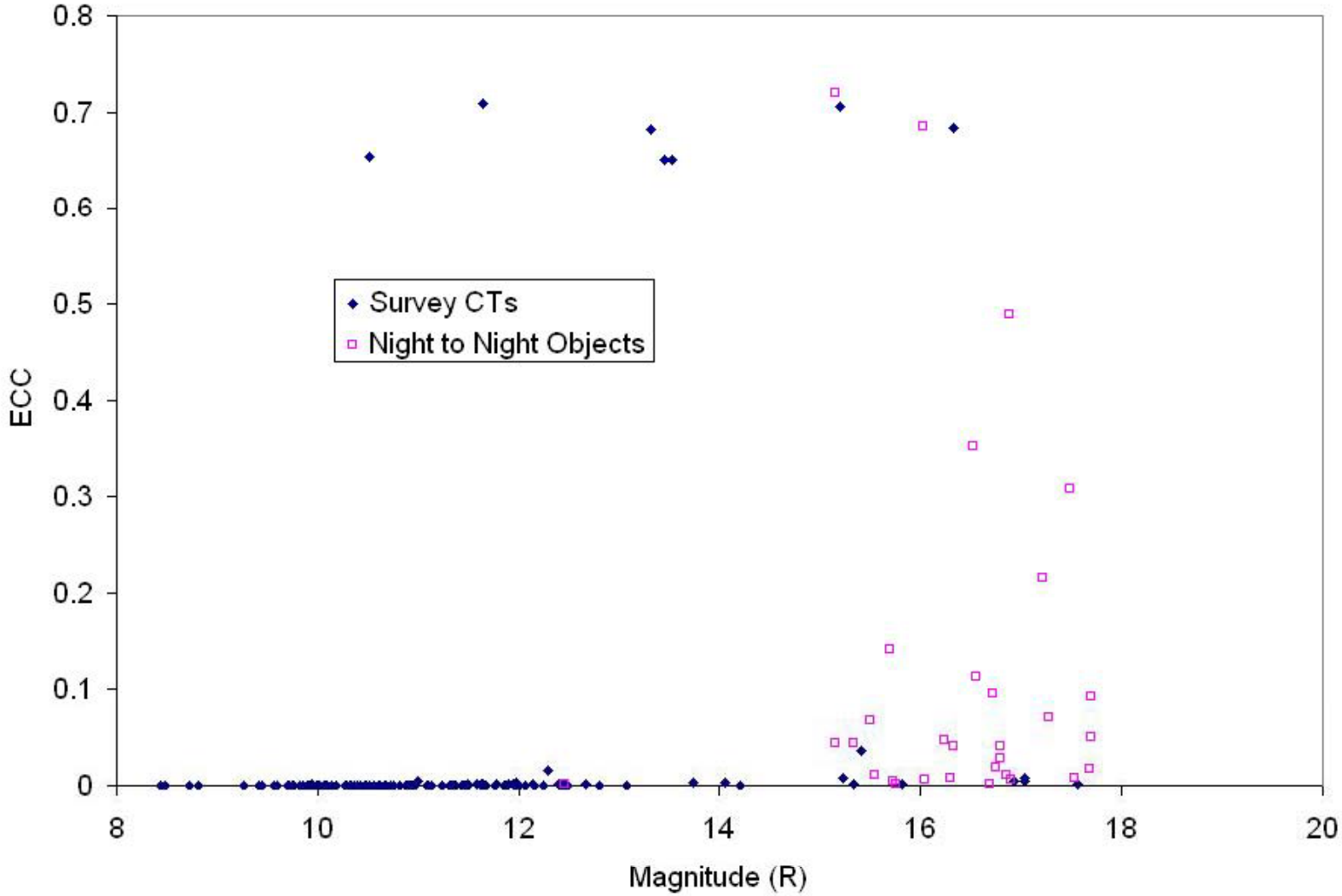
- **A few bright objects with known orbits tracked by 0.9-m and orbits compared with catalog. Excellent agreement.**

- **Following slides show March 2007 data – analysis complete.**

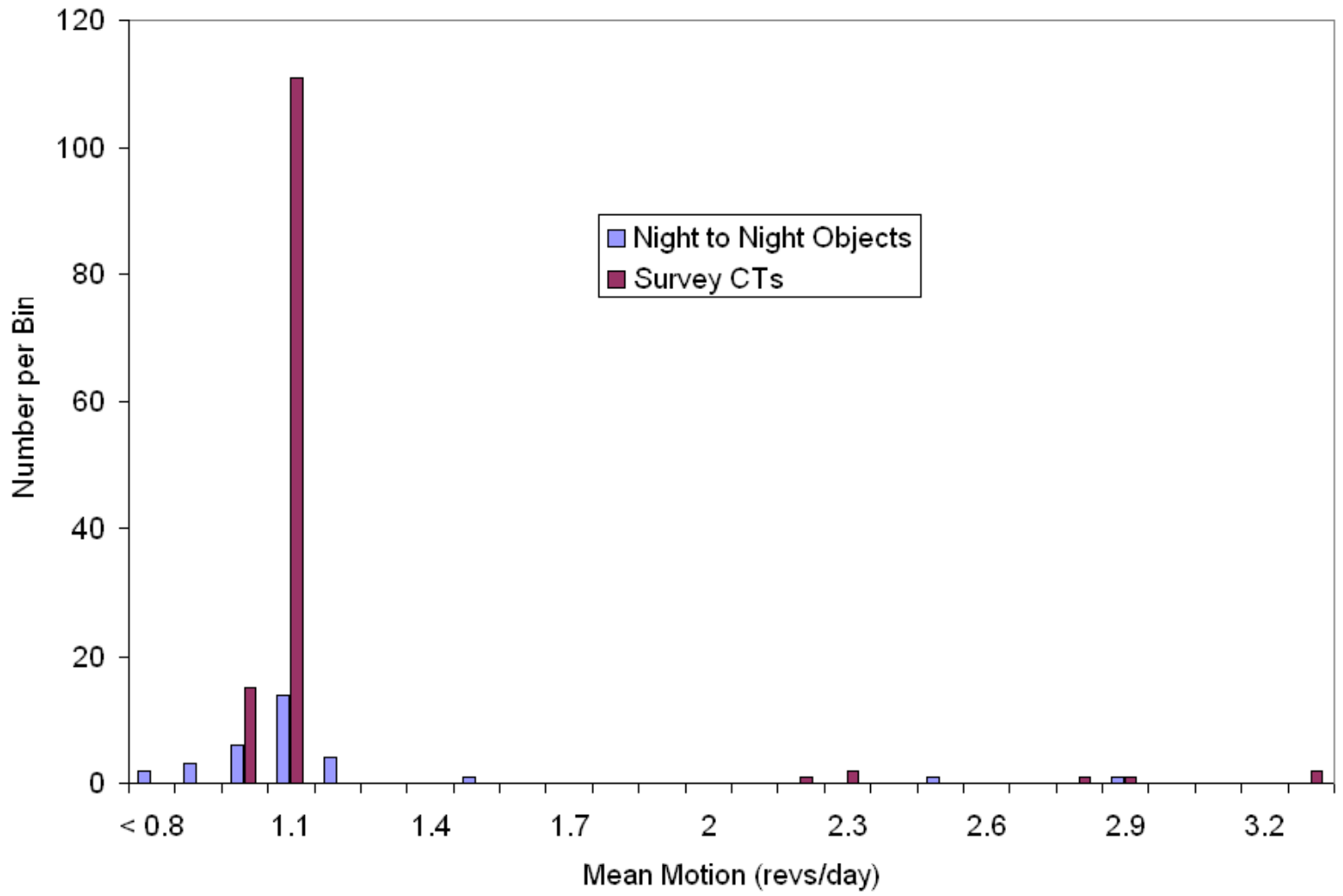
Inclination Distribution



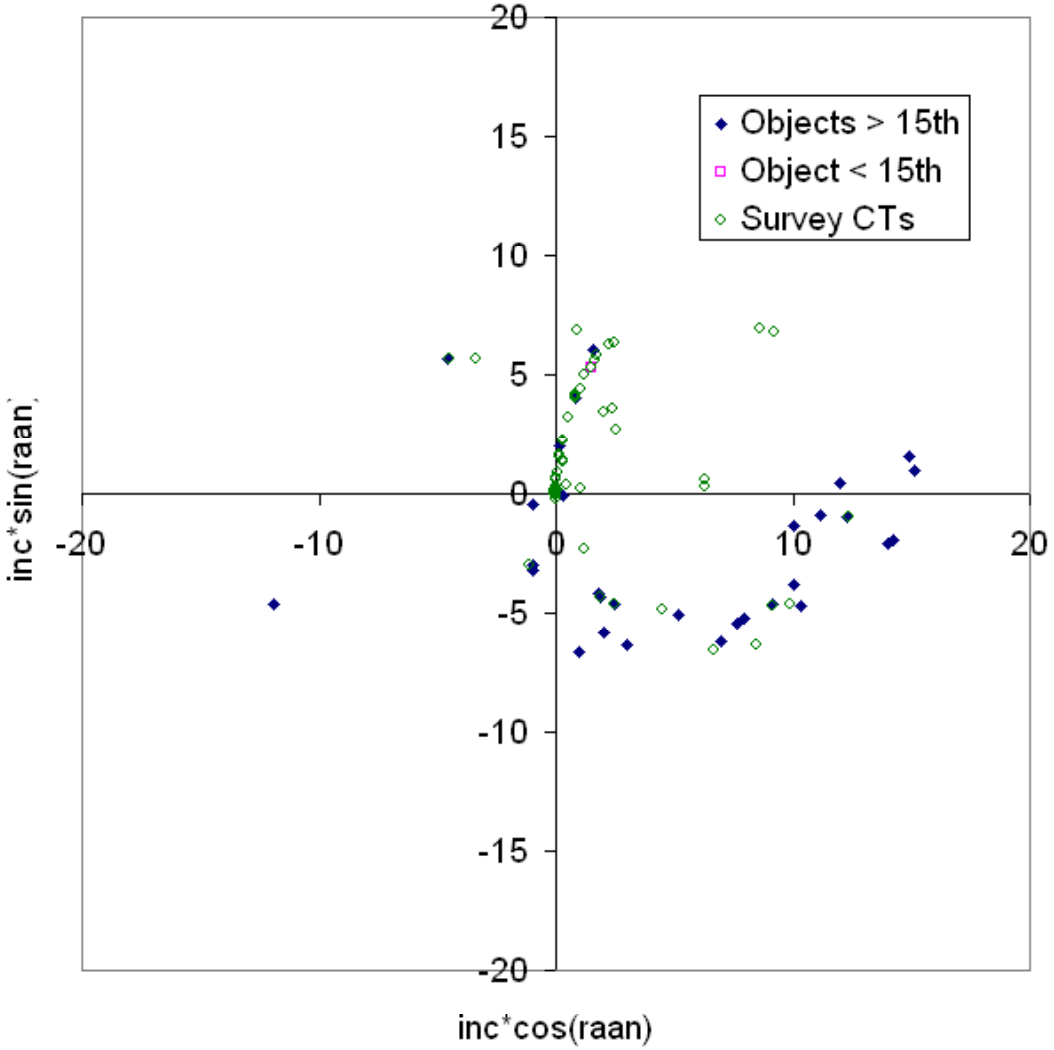
Magnitude versus Eccentricity



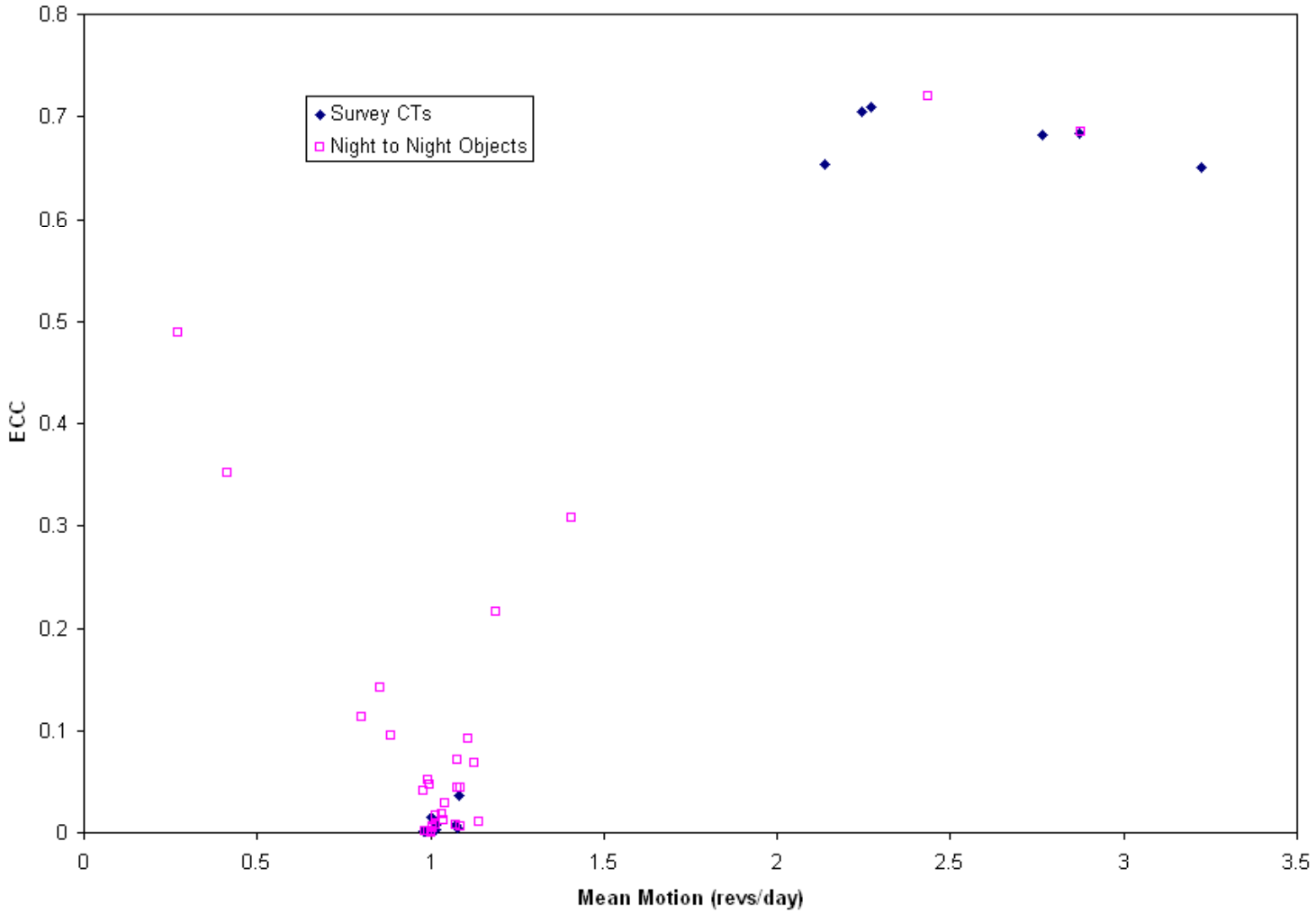
Mean Motion Distribution



Polar Plot


Objects > 15th
Object < 15th
Survey CTs
20
15
10
5
0
-5
-10
-15
-20
-20
-10
0
10
20
inc*sin(raan)
inc*cos(raan)

Mean Motion vs Eccentricity



Future

- **Most pressing goal - follow-up observations after several weeks with MODEST – determine A/M using ODTK.**

- **Goal – characterization of complete sample of faint GEO debris selected in a well defined, consistent manner.**